DTIC FILE COPY

ARL-SYS-TM-102

AR-004-598

(4)

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

AERONAUTICAL RESEARCH LABORATORY

MELBOURNE, VICTORIA

AD-A212 406

Aircraft Systems Technical Memorandum 102

RTSIN1 - A MODEL OF A STRAPDOWN INS ON A TWO-AXIS RATE TABLE (U)

by

R.B. Miller

Approved for Public Release

JULY 1989

89 9 18 071

AR-004-598

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
AERONAUTICAL RESEARCH LABORATORY

Aircraft Systems Technical Memorandum 102

RTSIN1 - A MODEL OF A STRAPDOWN INS ON A TWO-AXIS RATE TABLE (U)

by

R.B. MILLER

SUMMARY

This program simulates the outputs of a strapdown INS and the errors in those outputs, when the system is mounted on a two-axis rate table, undergoing a user-specified motion sequence, and when user-specified sensor and system errors are present. The strapdown INS is simulated by SINS1. The program contains a simulation of the rate table, which provides angular velocity and specific force at the reference point of the INS. The INS may be located at any user-specified position relative to the intersection of the table axes, and at any attitude relative to the table disc.

DSTO ARL
MELBOURNE

POSTAL ADDRESS: Director, Aeronautical Research Laboratory,
P.O. Box 4331, Melbourne, Victoria, 3001, Australia

LIST OF CONTENTS

1. RTSIN1 INTRODUCTION

A two-axis rate table is one of the most useful ~~items of~~ equipment for laboratory testing of strapdown inertial navigation systems (INS). In practice, tables are used both for angular positioning of the INS and for application of angular velocities about one or two axes. In the former, the INS may be aligned at some required attitude, and then rotated (perhaps quite slowly) to some other attitude, and left there "navigating" under the influences of gravity and earth rotation only, while its outputs are observed. A series of different such alignments and rotations can be used to deduce information about the system's sensor errors and characteristics. Additional constant or varying angular velocities may also be applied for investigations of the INS angular dynamics characteristics.

RTSIN1 simulates the outputs of a strapdown INS, and the errors in these outputs, when the system is mounted on a two axis rate table undergoing user specified rotations, and when certain specified sensor and system errors are present in the INS. The program models the rate table, the INS sensors and navigation algorithms. It provides output in data files from which the user may generate graphical output as required.

The table model provides angular velocity and specific force at the reference point of the INS, which may be located at any specified position relative to the intersection of the table axes. Angular velocity and specific force are in the coordinates of the nominal sensor axes, or body axes of the INS, which may be in any specified attitude relative to the table disc. The table has its outer axis level, aligned in an East-West direction. The inner axis moves in the North/South/Vertical plane. At this stage, no table errors are included in the model. A test run may be initialised with any angle, angular velocity, and angular acceleration on either axis. The run is defined by a sequence of angular accelerations, applied at a sequence of times, to either or both of the table axes.

The INS is modelled by SINS1, which is described in reference (1). For its input, SINS1 takes the angular velocity and specific force generated by the table model. As its output, SINS1 provides the strapdown IN system estimates of position, velocity, and attitude. SINS1 has two parts - the sensors segment and the navigator segment.

In the SINS1 sensor segment, angular velocity and specific force inputs, in

nominal INS Body coordinates, are sampled and integrated, giving "ideal" rate-integrating gyro and incremental-velocity accelerometer outputs. The "ideal" sensor outputs are then corrupted in the sensor segment with sensor characteristics and errors including misalignment, scale factor errors, fixed biases, and quantization. These simulated sensor outputs are the inputs for the navigator segment.

The SINS1 navigator segment samples the "sensors" outputs and calculates the strapdown system outputs. It uses a split frame algorithm, partitioned into fast, intermediate, and slow update rate segments, the repetition rates of which may be preset to suit requirements. Quaternions are used for body attitude and angular position relative to Earth, and the navigation axes are Wander azimuth/Down. Vertical channel navigation may be either pure-inertial or set to follow input altitude. Altitude smoothing is not incorporated.

Levelling and alignment of the navigator may be performed either by specifying errors in the initial attitude, or by using a simple "one shot" coarse alignment routine which uses the (unquantized and stationary) sensor outputs to estimate level and North. The navigator's initial position and velocity may also have specified errors included.

At specified time intervals, an output routine obtains the INS model's estimates of the system state, that is, the position, velocity, and attitude. Also, using the rate table state, it calculates "true" values. Errors in the INS estimates of system state are then calculated and may be written to diskfiles and/or the terminal.

2. RATE TABLE SEGMENT

This provides angular velocity and specific force at the INS reference point, given sequences of angular accelerations applied to either or both of the rate table axes.

2.1. Axes sets

These may be defined as follows (see also figure 1, for illustration of Table Axes Sets):

INERTIAL (I), having I3 along Earth's axis of rotation.

GEOGRAPHIC (G), having G1, G2, G3 as North, East, and Down. The origin is at the intersection of the table axes.

TABLE REFERENCE (R): with the inner axis horizontal (nominally North/South), and the outer axis assumed horizontal (nominally East/West), then R1 is the inner axis ("North" positive), R2 the outer axis ("East" positive), and R3 is down positive. The origin is at the intersection of table axes. For present purposes, it is assumed that R and G are equivalent. See figure 1(a).

TABLE INPUT (J): this set includes both of the table's driven axes, and is defined by a rotation about the outer axis through an angle E (ELEVation) from the R set. J1 is the table inner axis in any configuration, J2 is the table outer axis in any configuration, and J3 is orthogonal to J1 and J2. The origin is at the intersection of table axes. See figure 1(b).

TABLE DISC (D): is defined by a rotation from the J set about the inner axis, through an angle B (BANK). D1 is coincident with the table inner axis J1, D2 and D3 are parallel to the table disc, and rotate with it. The origin is at the intersection of table axes. (R to D is nominally the same as G to aircraft body axes.) See figure 1(c).

The INS reference point P has a vector displacement $\underline{r}$ from the above origins. As the INS is fixed to the disc, $[\underline{r}]^D$ is constant.

IMU BODY (B): this is the orthogonal set of nominal sensor axes in the IMU. The origin is at P. There may be any angular relationship between D and B. This relationship is assumed constant in any run, and is defined by the initialisation conditions, whereby the initial attitudes of both the IMU and the table disc are defined separately, and their relationship is calculated by the initialisation routine.

2.2. Function

At each step of the simulation, values of table bank and elevation angular acceleration are obtained in accordance with the run specifications. These are integrated to provide instantaneous values of table angular rates and angles. From

these the angular velocity and specific force at the IMU arising from table movement are calculated in D axes coordinates. The transformation from R to D axes is also calculated from table angles and used to resolve Earth rate and gravity vectors into D axes, which are added to the table movement effects.

Total angular velocity and specific force are then transformed from D to B axes coordinates. The D to B transformation C_D^B is constant and is calculated by the initialisation process. This is done by calculating the initial R to B and R to D transformations and combining these to get the D to B transformation.

In those parts of a simulation run where table angular velocities and angular accelerations about both axes are zero, the inputs to the IMU remain constant. In this case, the rate table segment is not called, and the previously calculated IMU inputs are used: this is to save computer loading.

2.2.1. Angular Velocity of IMU

The angular velocity of the B axes is the same as that of the D axes. It consists of Earth angular velocity plus table angular velocity:

$$\underline{\omega}_{ID} = \underline{\omega}_{IG} + \underline{\omega}_{RD} \qquad (\underline{\omega}_{GR} = 0)$$

in D coordinates:

$$[\underline{\omega}_{ID}]^D = C_R^D \, C_I^G \, [\underline{\omega}_{IE}]^I + [\underline{\omega}_{RD}]^D \qquad (C_G^R = I)$$

i.e.:

$$[\underline{\omega}_{ID}]^D = C_R^D \, [\underline{\omega}_{IE}]^R + [\underline{\omega}_{RD}]^D \qquad \text{...(1)}$$

2.2.2. Specific Force on IMU

Specific force at the INS reference point P arises from gravity support plus the effects of table rotation with the offset of P from the table axes origin 0, i.e., centripetal force and tangential acceleration.

If P has velocity $\underline{v}$ relative to 0, then specific force at P is given by:

$$\underline{SFp} = \left[\frac{d\underline{v}}{dt}\right]_R - \underline{g}$$

i.e. $$[\underline{SFp}]^D = \left[\frac{d\underline{v}}{dt}\right]^D_R - C^D_R\,[\underline{g}]^R \qquad \text{....(2)}$$

Apply Coriolis' equation to $\underline{v}$:

$$\left[\frac{d\underline{v}}{dt}\right]_R = \left[\frac{d\underline{v}}{dt}\right]_D + \underline{\omega}_{RD} \times \underline{v} \qquad \text{...(3)}$$

but, $$\underline{v} = \underline{\omega}_{RD} \times \underline{r} \qquad \text{...(4)}$$

and therefore $$\left[\frac{d\underline{v}}{dt}\right]_D = \left[\frac{d\underline{\omega}_{RD}}{dt}\right]_D \times \underline{r} \qquad \text{...(5)}$$

substitute (4) and (5) into (3):

$$\left[\frac{d\underline{v}}{dt}\right]_R = \left[\frac{d\underline{\omega}_{RD}}{dt}\right]_D \times \underline{r} + \underline{\omega}_{RD} \times (\underline{\omega}_{RD} \times \underline{r}) \qquad \text{...(6)}$$

express (6) in D coordinates and substitute into (2):

$$[\underline{SFp}]^D = [\dot{\underline{\omega}}_{RD}]^D \times [\underline{r}]^D + [\underline{\omega}_{RD}]^D \times ([\underline{\omega}_{RD}]^D \times [\underline{r}]^D) - C^D_R\,[\underline{g}]^R \qquad \text{...(7)}$$

2.2.3. Evaluation of angular velocity and specific force

Equations (1) and (7) above may be evaluated in terms of the rate table angles B and E, angular rates $\dot{B}$ and $\dot{E}$, and angular accelerations $\ddot{B}$ and $\ddot{E}$.

The direction cosine matrix for R to D coordinate transformation is calculated:

$$C_R^D = \begin{bmatrix} \cos(E) & 0 & -\sin(E) \\ \sin(E)\sin(B) & \cos(B) & \cos(E)\sin(B) \\ \sin(E)\cos(B) & -\sin(B) & \cos(E)\cos(B) \end{bmatrix}$$

Angular velocity is specified in J axes:

$$[\underline{\omega}_{RJ}]^J = \begin{bmatrix} 0 \\ \dot{E} \\ 0 \end{bmatrix} \quad \text{and} \quad [\underline{\omega}_{JD}]^J = \begin{bmatrix} \dot{B} \\ 0 \\ 0 \end{bmatrix}$$

therefore,

$$[\underline{\omega}_{RD}]^J = \begin{bmatrix} \dot{B} \\ \dot{E} \\ 0 \end{bmatrix}$$

In D axes coordinates,

$$[\underline{\omega}_{RD}]^D = C_J^D \begin{bmatrix} \dot{B} \\ \dot{E} \\ 0 \end{bmatrix} = \begin{bmatrix} \dot{B} \\ \dot{E}.\cos(B) \\ -\dot{E}.\sin(B) \end{bmatrix}$$

Equation (1) may now be evaluated.

Also,

$$[\dot{\underline{\omega}}_{RD}]^D = \begin{bmatrix} \ddot{B} \\ \ddot{E}.\cos(B) - \dot{E}.\dot{B}.\sin(B) \\ -\ddot{E}.\sin(B) - \dot{E}.\dot{B}.\cos(B) \end{bmatrix}$$

Equation (7) may now be evaluated.

Angular velocity and specific force are next transformed from D to B axes coordinates:

$$[\underline{\omega}_{IB}]^B = C_D^B [\underline{\omega}_{ID}]^D \quad \text{and} \quad [\underline{SF}_p]^B = C_D^B [\underline{SF}_p]^D$$

($\underline{\omega}_{IB}$ is equivalent to $\underline{\omega}_{ID}$).

3. PROGRAM IMPLEMENTATION

The structure of program RTSIN1 is shown in figure 2. It consists of an initialisation segment, a time-stepping loop, and a closing down segment.

3.1. Initialisation

The initialisation segment includes reading of data files, setting up the rate table model and the INS model, and preparing program output arrangements.

3.1.1. Input Data Files

After entry to RTSIN1, routine READFILE is called. This opens, reads, and closes the data files and does preliminary data checking and scaling.

The first file to be read is SIMDATA - the file of initialisation data for the run. This must be in the same directory as the RTSIN1 run file. SIMDATA contents are described in appendix 1; they include a list of filenames for input and output.

The input files are an INS initial conditions data file and a rate table initial conditions and run profile data file. Their contents are described in appendices 2 and 3 respectively. The INS initial conditions file also includes two data file pathnames required by SINS1. These files contain sensor characteristics data and navigator run data as described in appendices 4 and 5 respectively, which are reproduced from Reference 1.

3.1.2. Rate Table Model Initialisation

This is achieved by calls to RTABINI and RTDYN.

Routine RTABINI calculates the components of Earth rate and gravity support force in table reference (R) axes, using the Earth data from the rate table data file. It also calculates the constant Table Disc (D) to IMU Body (B) axes coordinate

transformation: that is, between the initial RHEAD, RELEV, and RBANK of the IMU and the initial TELEV and TBANK of the Table ("THEAD" is zero for this model). Finally, change times in table angular acceleration specifications are converted to counts of the sensor cycle period, which is twice the simulation step period in this case.

Routine RTDYN calculates the instantaneous angular velocity and specific force experienced at the reference point of the IMU, in IMU Body (i.e. 'nominal sensor') axes. These calculations are as described in section 2.2 above.

3.1.3. Initialisation of SINS1

This is achieved by a call to routine INISINS1. This calculates the initial true velocity components (RVNORTH, RVEAST, RVDOWN) of the IMU reference point in Geographic axes coordinates (which are assumed equivalent to the Table Reference axes). This is done by transforming the velocity of the IMU (relative to the table axes origin) in Table Disc axes coordinates, into Table Reference coordinates. Both the velocity and the transformation matrix were calculated in RTDYN. INISINS1 also sets up the initial variables, counters, flags, and input data required by SINS1 for initialisation, calls it, and records its output for processing by output routine RTOUTPUT.

3.1.4. Output Initialisation

On the first call to RTOUTPUT, the output files are opened, some constants are calculated, and a run through the routine is made to obtain the initial output values. Functions of RTOUTPUT are described in detail below.

3.2. Time Stepping Loop

After initialisation, the program proceeds as a time stepping simulation until the run is completed.

On entry to the loop, time is incremented, and the new values of rate table angular velocities and attitudes are calculated with a call to RTANG. This routine takes the current values of angular acceleration, in each table axis, and integrates them twice to obtain the angular velocities and attitudes. In the present version of the program, it is assumed that the angular accelerations are constant over a step, so rectangular integrations for velocities and trapezoidal integrations for attitudes are

of adequate order. If varying angular accelerations are to be accommodated, the order of the integrations would have to be increased. RTANG sets a flag MOVING according to whether or not there is movement about either axis.

If there has been movement about either table axis, a call is made to RTDYN to calculate the IMU environment. If there has been no movement, this call is omitted and the previous values of environment are used: this is to reduce computer loading.

A test is made to see if INS output is required for this step, and a flag is set accordingly. A call is then made to RUNSINS1, which is the run time handler for SINS1. RUNSINS1 sets up the various counters, flags, and input data required by SINS1, calls it, and records its output if necessary.

A call is then made to routine RTOUTPUT (see below). This creates and writes output if required in this step.

A check is then made to see whether a change in angular acceleration in either axis will occur at the end of the present step, which is equivalent to the beginning of the next step. If a change is to occur, the environment of the IMU, at the instant after the change, is calculated by a call to RTDYN with the new acceleration. This is passed, via RUNSINS1, to SINS1 for the initial conditions for the SINS1 sensor model in the next simulation step (see reference 1).

RTSIN1 now tests whether the run is finished; if not, it returns to the beginning of the loop for the next step.

3.2.1. Program Output

During the time stepping loop, two files of output data are written: one is a record of the rate table true angles, and angular velocities and accelerations: the other is a record of the INS errors. These files, whose names are specified by the user in SIMDATA, are written by calls to routine RTOUTPUT.

In RTOUTPUT, the INS position and velocity errors are obtained by subtracting the "true" value from the INS estimate of each quantity. True velocities in Geographic axes are calculated from the velocities in Table Disc axes and the Table Disc to Reference transformation matrix, both of which have been calculated in RTDYN. The INS attitude outputs are not used, because there are singularities and possible ambiguities in the angular outputs. The INS estimates of Wander to

Body quaternion $\bar{Q}'_{WB}$ are used to calculate attitude errors directly:

from true rate table angles, calculate true Disc to Wander quaternion $\bar{Q}_{DW}$ (true wander angle is constant, as the table position is constant);

from RTABINI, we have the true Body to Disc quaternion $\bar{Q}_{BD}$, therefore the true Body to Wander quaternion $\bar{Q}_{BW}$ is given by:

$$\bar{Q}_{BW} = \bar{Q}_{BD} \; (*) \; \bar{Q}_{DW}$$

The quaternion $\bar{Q}_{\epsilon}$ of the attitude error in the INS is then given by:

$$\bar{Q}_{\epsilon} = \bar{Q}'_{WB} \; (*) \; \bar{Q}_{BW}$$

assuming the attitude error angles are small, $\bar{Q}_{\epsilon}$ may be written:

$$\bar{Q}_{\epsilon} = 1 \; , \; \tfrac{1}{2} \, \underline{\Phi}$$

where $\underline{\Phi}$ is the "rotation vector" of the attitude error, and its components are the bank, elevation, and yaw errors respectively.

NOTE that these are the bank, elevation, and yaw errors of the system's estimate of Wander Axes relative to the "true" Wander Axes: they are not the usual errors in the Body Axes.

The INS errors are written as an ASCII file of data in columns. The maximum and minimum values of each error quantity are recorded and on the final entry to RTOUTPUT, they are written into a file the name of which was specified by the user in SIMDATA. This data is useful for specifying axes when preparing graphical output.

3.3. Closing Down

On the final entry to RTOUTPUT, the INS errors file and the rate table true angular data file are closed, and the maximum and minimum errors file as above is opened, written, and closed.

After exiting the stepping loop, routine RTSRECORD is called. This copies all the input files into one record file, the name of which was specified in SIMDATA.

4. SCOPE FOR FURTHER DEVELOPMENT

The table rotation sequence is defined by a series of constant angular accelerations and times for which they apply. This is not always the most convenient format for the user. An alternative might be to define a required series of changes in angle and/or angular velocity about each table axis, for a specified angular acceleration. This could be achieved by an extension to the time calculation part of RTABINI, with appropriate changes to the input file format and to the part of READFILE which reads table sequence data.

The table model now requires stepwise constant angular accelerations. As discussed in section 3.2, higher orders of integration in RTANG could be included to accommodate varying accelerations. In particular, it may be found useful to incorporate sinusoidal motion about either or both table axes. This could be achieved with either higher order integration, or by analytical methods, or a combination of both, in RTANG.

REFERENCES

NO.	AUTHOR	TITLE
1	R.B. Miller	SINS1: A model of a strapdown inertial navigation system. ARL-SYS-TM-101 Jul 1989

APPENDIX 1 - Program Initialisation File

The first file to be read is SIMDATA - the file of initialisation data for the run. This must be in the same directory as the RTSIN1 run file. Contents of SIMDATA, using variable names as in RTSIN1 are:

STEPMUSEC	ENDSECS	SSPEROUT			
FNINSINI	FNRTABLE	FNTABREF	FNERRORS	FNRANGES	FNRECORD
FPATH					
TTYFLG					

The first line is timing data: Microsec per simulation step, Total no. of seconds in run, No. of simulation steps per output write. The second line has character variables containing filenames for input and output files. These are:

FNINSINI	(input) INS attitude and initialisation data
FNRTABLE	(input) Rate table initialisation and run profile data
FNTABREF	(output) Rate table "true" angles, angular velocities and angular accelerations
FNERRORS	(output) INS errors through run
FNRANGES	(output) maximum and minimum values in above
FNRECORD	(output) record file of all initialisation data

Next is the (existing) directory name in which the output files are to be written. Finally the terminal output flag which should be 2 for full output, 1 for partial output (time only), or 0 for no terminal output.

APPENDIX 2 - INS attitude and initialisation data file

The name of this file is specified by the user in SIMDATA. Content of the file, using variable names as in the program, is:

RLON RLAT RALPHA RHEIGHT RBANK RELEV RHEAD
ELON ELAT ALPHA EHEIGHT EVNORTH EVEAST EVDOWN EBANK EELEV EHEAD
UNI
FNINSSEN
FNINSNAV
ALYNFLAG HGHTFLAG

The first line is a set of reference (true) quantities (degrees, metres) representing the INS initial conditions. The initial true velocities are calculated in INISINS1 from the rate table's initial angular velocities and the IMU displacement.

The second line is a set of initial error quantities (degrees, metres, metres/sec.), used in setting up the simulated INS. The actual value used by the INS for any variable is the Reference value plus this error value.

UNI is a fortran unit no. for use by SINS1. It may be any integer value greater than 8 which is available to the user.

FNINSSEN and FNINSNAV contain pathnames (up to 80 characters each) for SINS1 sensor characteristics data and navigator data files respectively. These files must be prepared by the user, unless the SINS1 default values are to be used: their formats are described in Appendices 4 and 5. If either has the value '' its default is used (see reference 1).

ALYNFLAG and HGHTFLAG are alignment and height flags respectively, and each may have values 0 or 1. If ALYNFLAG is 1, the coarse one-shot INS alignment will be carried out; if it is 0, the data values of heading, bank, and elevation will be used. If HGHTFLAG is 0, the reference values of height will be used by SINS1, and its vertical velocity output will be set to zero; if it is 1, the vertical channel is free inertial (and therefore unstable).

APPENDIX 3 - Rate table initialisation and run profile data file

The name of this file is specified by the user in SIMDATA. Content of the file, using variable names as in the program, is:

EQRAD INVELL ERATE EQATGRAV GRAVLAT GRAVALT
TBANK TELEV TAVBANK TAVELEV TAABANK TAAELEV
RIMU1 RIMU2 RIMU3
AACHNGES
TB(AACHNGES)
AACB(AACHNGES)
TE(AACHNGES)
AACE(AACHNGES)

The first line consists of Earth data quantities. They have the same variable names as those used in the navigator data file (appendix 5), however, these quantities are used only in the rate table model segment, and their values do not have to be identical.

The second line consists of initial true rate table conditions (degrees, seconds) they are: bank and elevation axes angles, angular velocities, and angular accelerations.

The third line is rate table axes origin to IMU reference point displacement in Table Disc coordinates (metres).

Next is the specification of the table angular acceleration sequence data. This consists of:

Number of a/acc changes in either bank or elevation (maximum 50)
Table ang. acc. change times (Bank) - seconds
Bank a/acc values at & after each TB - degrees/sec^2
Table ang. acc. change times (Elev) - seconds
Elev a/acc values at & after each TE - degrees/sec^2

The TB,TE,AACB,AACE arrays should all be filled to at least AACHNGES - padding values of zero may be used. Times when angular acceleration changes should be selected to occur at even multiples of the simulation step period.

APPENDIX 4 - Sensor data file format

The name of this file is specified by the user in the INS attitude and initialisation data file. An example of its contents is:

```
0                                       /* Gyro misalignment
1.0 0.0 0.0
0.0 1.0 0.0
0.0 0.0 1.0
0                                       /* Acc misalignment
1.0 0.0 0.0
0.0 1.0 0.0
0.0 0.0 1.0
1.0 1.0 1.0         1.0 1.0 1.0         /* Gyros, Accs, s/factors
0.0 0.0 0.0         0.0 0.0 0.0         /* Gyros, Accs, biases
0.0 0.0                                 /* Gyros, Accs, quant. levels
```

Names of the corresponding variables in SINS1 are:

```
GYMIS
GYMX11     GYMX12     GYMX13
GYMX21     GYMX22     GYMX23
GYMX31     GYMX32     GYMX33
ACMIS
ACMX11     ACMX12     ACMX13
ACMX21     ACMX22     ACMX23
ACMX31     ACMX32     ACMX33
GYSF(1)    GYSF(2)    GYSF(3)    ACSF(1)    ACSF(2)    ACSF(3)
GYBIAS(1)  GYBIAS(2)  GYBIAS(3)  ACBIAS(1)  ACBIAS(2)  ACBIAS(3)
GQLEVEL    AQLEVEL
```

In the above, the first letter being G or A denotes gyro or accelerometer respectively. GYMIS and ACMIS are integer, all others are real.

GYMIS is used to indicate if any misalignments exist in the misalignment matrix GYMX. If it is 0, perfect alignment is assumed, and the values in the components of GYMX are not used, although they must be in the data file. For any other value, the GYMX are used.

GYMX are misalignment factors. GYMXjk means that the gyro on the j axis senses GYMXjk times the integral of body rate about the k axis.

GYSF are scale factor errors. The output of the gyro on the j axis is multiplied by GYSF(j).

GYBIAS(j) are fixed biases, in degrees per hour. These are converted to radians per sensor cycle, and added to the respective gyro's integrated output.

GQLEVEL is the quantization level for all gyros, in arcseconds. This may take a zero value, in which case the quantization level is the resolution (double precision) of the computer used to run the program.

Accelerometer characteristics are similarly described, except that the misalignments operate on the integrals of specific force, and the units for fixed biases are metres per second^2, and quantization is in metres per second.

Values quoted above are default values, which assume the system is error free.

APPENDIX 5 – Navigator data file format

The name of this file is specified by the user in the INS attitude and initialisation data file. An example of its contents is:

6378135.0	298.26	0.0000729211515	9.780333	0.0052884	2.014
2	16	16			
10	10	7	1		

Names of the corresponding variables in SINS1 are:

EQRAD	INVELL	ERATE	EQATGRAV	GRAVLAT	GRAVALT
SSPERFAST	SSPERIMED	SSPERSLOW			
QWBNORM	QEWNORM	QUPORDER	AP9MOD		

The first line consists of Earth quantities. They are all real.

EQRAD	is the equatorial radius in metres
INVELL	is inverse of ellipticity
ERATE	is Earth rate in radians per second
EQATGRAV	is gravity at the equator in metres per second^2
GRAVLAT	is a factor for variation of gravity with latitude
GRAVALT	is a factor for variation of gravity with altitude

The second line are simulation steps (increments of SIMSTEPCTR) per navigation algorithm step. They are all integers.

SSPERFAST is the number of steps per call to NAVFAST. It may be any even integer.

SSPERIMED is the number of steps per call to NAVIMED. It must be an even multiple of SSPERFAST.

SSPERSLOW is the number of steps per call to NAVSLOW. It should be an integer multiple of SSPERIMED.

The third line quantities are integers.

QWBNORM is the minimum number of times QWB may be updated between normalization.

QEWNORM is the number of times QEW is updated between normalization.

QUPORDER is the order of calculation of the updating quaternion in NAVFAST. It should be 3, 5 or 7.

AP9MOD is a flag for higher order body axes velocity calculation in NAVFAST. If it is 0, a *simple calculation* is performed: otherwise a 4th order Runge-Kutta is used.

Values listed above are the default values.

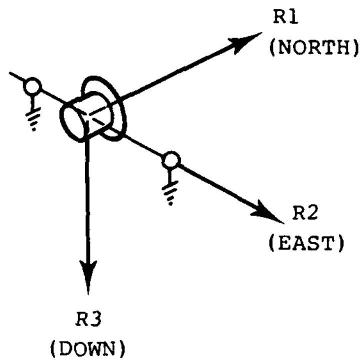

FIG. 1 (a) - TABLE REFERENCE AXES (R)

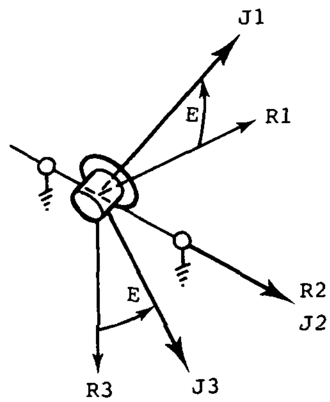

FIG. 1 (b) - TABLE INPUT AXES (J)

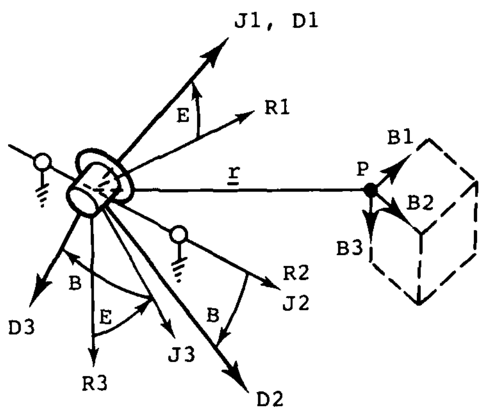

FIG. 1 (c) - TABLE DISC AXES (D)
AND INS BODY AXES (B)

FIG. 1. TABLE AXES

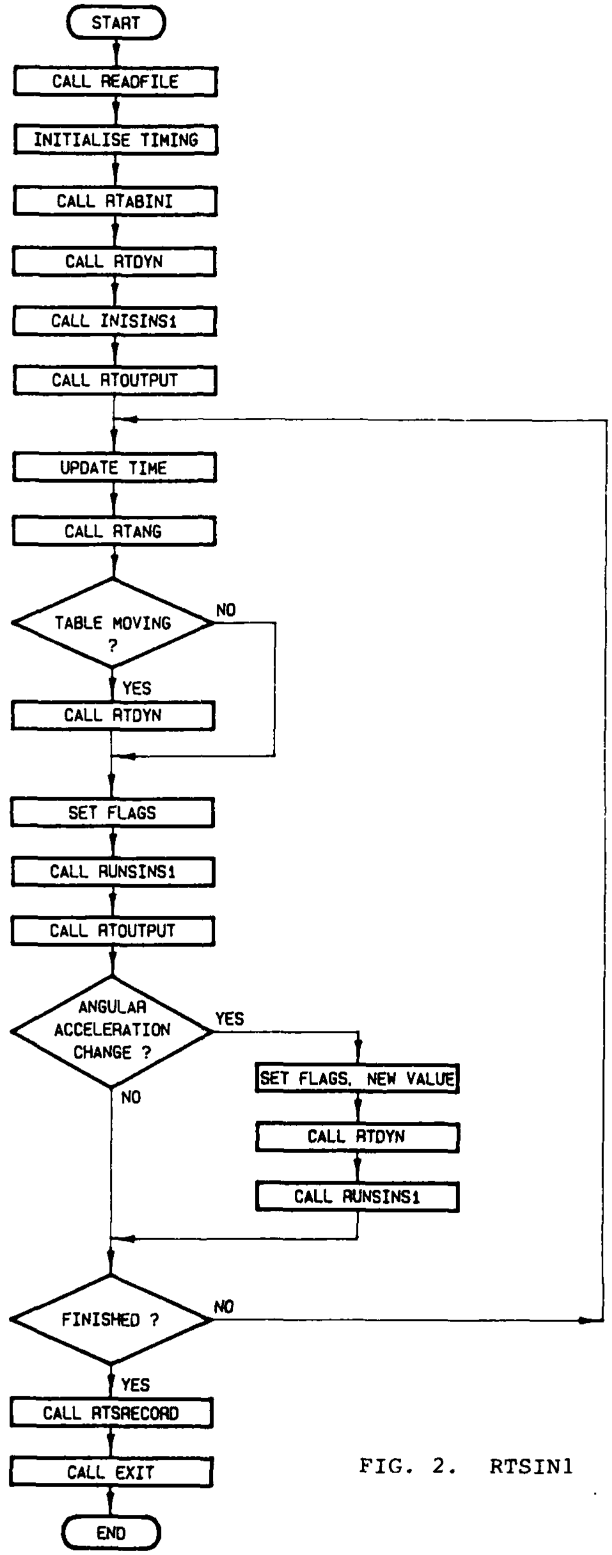
START
CALL READFILE
INITIALISE TIMING
CALL RTABINI
CALL RTDYN
CALL INISINS1
CALL RTOUTPUT
UPDATE TIME
CALL RTANG
TABLE MOVING ?
NO
YES
CALL RTDYN
SET FLAGS
CALL RUNSINS1
CALL RTOUTPUT
ANGULAR ACCELERATION CHANGE ?
YES
NO
SET FLAGS, NEW VALUE
CALL RTDYN
CALL RUNSINS1
FINISHED ?
NO
YES
CALL RTSRECORD
CALL EXIT
END

FIG. 2. RTSIN1

DISTRIBUTION

AUSTRALIA

Department of Defence

Defence Central

Chief Defence Scientist
Assist Chief Defence Scientist, Operations (shared copy)
Assist Chief Defence Scientist, Policy (shared copy)
Director, Departmental Publications
Counsellor, Defence Science (London) (Doc Data sheet only)
Counsellor, Defence Science (Washington) (Doc Data sheet only)
S.A. to Thailand Military R and D Centre (Doc Data sheet only)
S.A. to the DRC (Kuala Lumpur) (Doc Data sheet only)
OIC TRS, Defence Central Library
Document Exchange Centre, DISB (18 copies)
Joint Intelligence Organisation
Librarian H Block, Victoria Barracks, Melbourne
Director General - Army Development (NSO) (4 copies)

Aeronautical Research Laboratory

Director
Library
Superintendent - Aircraft Systems
Author: R.B. Miller
PO/FMG (4 copies)

Materials Research Laboratory

Director/Library

Defence Science & Technology Organisation - Salisbury

Library

Navy Office

Navy Scientific Adviser (3 copies Doc Data sheet)

Army Office

Scientific Adviser - Army (Doc Data sheet only)

Air Force Office

Air Force Scientific Adviser (Doc Data sheet only)
Technical Division Library

Universities and Colleges

Adelaide
Barr Smith Library

Flinders
Library

La Trobe
Library

Melbourne
Engineering Library

Monash
Hargrave Library

Newcastle
Library

New England
Library

Sydney
Engineering Library

NSW
Physical Sciences Library
Library, Australian Defence Force Academy

Queensland
Library

Tasmania
Engineering Library

Western Australia
Library

RMIT
Library

UNITED KINGDOM
Royal Aircraft Establishment, Farnborough
Library
Superintendent, RN1 Division
Mr R.A. Frampton, RN1 Division

SPARES (10 copies)
TOTAL (64 copies)

AL 149 DEPARTMENT OF DEFENCE

DOCUMENT CONTROL DATA

PAGE CLASSIFICATION
UNCLASSIFIED

PRIVACY MARKING

1a. AR NUMBER	1b. ESTABLISHMENT NUMBER	2. DOCUMENT DATE	3. TASK NUMBER
AR-004-598	ARL-SYS-TM-102	JULY 1989	DST 86/064

4. TITLE
RTSIN1 - A MODEL OF A STRAPDOWN INS ON A TWO-AXIS RATE TABLE

5. SECURITY CLASSIFICATION (PLACE APPROPRIATE CLASSIFICATION IN BOX(S) IE. SECRET (S), CONF.(C) RESTRICTED (R), UNCLASSIFIED (U)).

DOCUMENT	TITLE	ABSTRACT
U	U	U

6. NO. PAGES
23

7. NO. REFS.
1

8. AUTHOR(S)
R.B. MILLER

9. DOWNGRADING/DELIMITING INSTRUCTIONS
Not applicable.

10. CORPORATE AUTHOR AND ADDRESS
AERONAUTICAL RESEARCH LABORATORY
P.O. BOX 4331, MELBOURNE VIC 3001

11. OFFICE/POSITION RESPONSIBLE FOR:
SPONSOR DSTO
SECURITY -
DOWNGRADING -
APPROVAL -

12. SECONDARY DISTRIBUTION (OF THIS DOCUMENT) Approved for public release.

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH ASDIS, DEFENCE INFORMATION SERVICES BRANCH, DEPARTMENT OF DEFENCE, CAMPBELL PARK, CANBERRA, ACT 2601

13a. THIS DOCUMENT MAY BE ANNOUNCED IN CATALOGUES AND AWARENESS SERVICES AVAILABLE TO....
No limitations.

13b. CITATION FOR OTHER PURPOSES (IE. CASUAL ANNOUNCEMENT) MAY BE [X] UNRESTRICTED OR [ ] AS FOR 13a.

14. DESCRIPTORS
Inertial navigation
Strapdown navigational systems
Computerized simulation

15. DRDA SUBJECT CATEGORIES
0076D

16. ABSTRACT
This program simulates the outputs of a strapdown INS and the errors in those outputs, when the system is mountcd on a two-axis rate table, undergoing a user-specified motion sequence, and when user-specified sensor and system errors are present. The strapdown INS is simulated by SINS1. The program contains a simulation of the rate table, which provides angular velocity and specific force at the reference point of the INS, which may be located at any user-specified position relative to the intersection of the table axes, and attitude relative to the table disc.

PAGE CLASSIFICATION
UNCLASSIFIED
PRIVACY MARKING

THIS PAGE IS TO BE USED TO RECORD INFORMATION WHICH IS REQUIRED BY THE ESTABLISHMENT FOR ITS OWN USE BUT WHICH WILL NOT BE ADDED TO THE DISTIS DATA UNLESS SPECIFICALLY REQUESTED.

16. ABSTRACT (CONT.)

17. IMPRINT

AERONAUTICAL RESEARCH LABORATORY, MELBOURNE

18. DOCUMENT SERIES AND NUMBER	19. COST CODE	20. TYPE OF REPORT AND PERIOD COVERED
AIRCRAFT SYSTEMS TECHNICAL MEMORANDUM 102	725326	Work done 1985-1986

21. COMPUTER PROGRAMS USED

22. ESTABLISHMENT FILE REF.(S)

23. ADDITIONAL INFORMATION (AS REQUIRED)